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Thermal Control of Mars Rovers and Landers Using Mini Loop Heat Pipes

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ABSTRACT

The long term survival and operation of Mars landers and rovers depends critically on the thermal control of their batteries, electronics and the science equipment. The ambient atmospheric temperatures on Mars range from +10 °C during the day, to as low as –100 °C at night. Various passive thermal control techniques have been used in past Mars missions to keep the temperatures of the electronics, science equipment, and batteries in landers and rovers within their acceptable limits. Of all the equipment used in future Mars rovers, the Lithium-Ion secondary battery is the most temperature sensitive. Batteries can age prematurely at elevated temperatures (above 40 °C) and electrolytes can freeze at low temperature (below –30 °C). The temperature limits of the rover electronics and science is typically –40 to +40 °C.

Two miniature loop heat pipe (LHP) concepts were investigated for their suitability for the thermal control of future Mars rovers and the results of this investigation will be described in the paper. The miniature LHP offers several advantages for the thermal control of Mars rovers. The heat transfer requirement in Mars rovers is typically less than 100 Watts and this can be easily met by the miniature LHP. They have a wick of ½" diameter or smaller and transfer tubes of 1/16" diameter making them very lightweight. Further, their thin flexible transfer lines make it very easy to route and install the LHP in the tight space inside the rover.

The first concept investigated was a variable conductance loop heat pipe for battery thermal control. In this concept, the LHP configuration consisted of one evaporator and two condensers. The evaporator transfers the heat from a set of Radioisotope Heater Units (RHUs) to the condensers. One condenser was located on the battery and the other was an external radiator. A backpressure thermal control valve integrated into the LHP between the two condenser. To keep the battery temperature below the upper limit, the thermal control valve in the LHP opens to redirect the working fluid to an external radiator where excess heat is dumped to the atmosphere. To keep the battery temperatures above the lower limit, the system uses the PCM thermal storage module to store heat and a loop heat pipe (LHP) to transfer heat between a set of Radioisotope Heater Units (RHUs) and the battery.

The second concept consisted of miniature LHP in conventional configuration. This was investigated for its ability to provide thermal control for the high power amplifier on the rover during Martian diurnal environment. The LHP removes the heat from the amplifier when the temperature exceeds a pre set value and stops when operating when the temperature drops below a pre set value. Heaters installed on evaporator and compensation chamber are used to control the operation of the LHP.

The key findings from the experimental simulation of the Mars '03 rover thermal performance in the Martian environment will be presented in the paper. Many lessons are being learned during the development and implementation of these thermal technologies for Mars rover thermal control. Recommendations for the design and operation of miniature loop heat pipes for future space missions will be described in the paper.

Reference:

Birur, G.C., Johnson, K. R., Novak, K. S., and Sur, T. W., " Thermal Control of Mars Lander and Rover Batteries and Electronics Using Loop Heat Pipe and Phase Change Material Thermal Storage Technologies," SAE Technical Paper No 2000-01-2403, 30th International Conference on Environmental Systems, Toulouse, France, July 10-13, 2000.